5.0 RCM/AE DATA SOURCES, ANALYSIS & TOOLS

There are several data analysis techniques which are useful for RCM purposes; from the typical statistical processes found in an academic text like regression analysis, to special techniques developed for use in specific circumstances like the Weibull analysis. Personnel responsible for the development, management, and implementation of PM tasks must have an understanding of the various techniques and know when each is appropriate.

The analysis processes and data sources that an analyst should be most familiar with, and are most commonly used, are discussed within this section.

5.1 Data sources. Following are several sources for obtaining data required for RCM analysis or AE. This list is not all-inclusive.

5.1.1 Aviation 3-M Data. Navy 3-M data will probably be the most widely used data source for RCM analysis and contains various maintenance and flight data. Following are several methods of accessing 3-M data.

a. NALDA

b. ECA reports

c. LMDSS

d Naval Aviation Maintenance Support Office (NAMSO) Maintenance/Flight Hour Reports

e. SRC database

f. Engine Component Improvement Feedback Reports (ECIFR)

5.1.2 ISST/IPT In-Service Engineering Data. The following data should be collected, archived, and made available for analysis. Some programs have automated databases which contain various “logs” which track the data and allow for timely automated retrieval of historical data.

a. Technical Directives (TDs)

b. EIs

c. Hazard Reports (HRs)

d. HMRs

e. Depot Maintenance Data Sheets

f. Structurally Significant Item Reports (SSIRs)

g. Aircraft Service Period Adjustment (ASPA) Reports

h. MERs

i. RCM History Logs

j. TPDRs

k. Aircraft Bureau Number (BUNO) Data

l. Miscellaneous History Data

5.1.3 Contractor Analyses/Reports. Through contract requirements, contractor data should be delivered to the government. This data contains various analysis reports which are essential inputs for RCM analysis such as:

a. Fracture Mechanics Analysis Reports

b. Stress Analysis Reports

c. Loads Analysis

d. AE Analysis Reports

5.1.4 Default Data. In the absence of cost/logistical data the NAVAIR Level of Repair Analysis (LORA) Default Data Guide should be reviewed and utilized as applicable.

5.2 Degradation Analysis. Degradation analysis uses evidence of physical or functional degradation as a basis for the design of a PM task. A specific degradation analysis focuses on the single EFM which drove the PM requirement, not upon the general equipment deterioration. The analysis uses measurements to determine the onset and rate of progression of a condition that is expected to be highly correlated to the specific EFM. There are many kinds of degradation. Some of the most common are:

a. Wear (material loss due to abrasion or erosion)

b. Corrosion (material loss due to chemical reactions)

c. Hardening/Softening (particularly characteristic of non-metals)

d. Cracking (often associated with fatigue)

Degradation analysis is most appropriately performed in association with OC PM tasks. Its primary purpose is to either verify the effectiveness of an existing OC task interval, or adjust the interval to the optimal frequency. This is done by developing degradation curves (wear versus time, area of corrosion versus time, etc.), defining a potential failure condition, then determining the interval between potential and functional failure. From the interval between potential and functional failure, task intervals can be developed which will avoid functional failures.

5.3 Survival Analysis. Survival analysis is a generic term that describes the analysis of censored data. Different computer programs have different techniques for handling and analyzing these data. Several examples of survival analysis are provided below.

5.3.1 Life Regression. Statistical Analysis Software (SAS) uses Life Regression (PROC LIFEREG) for data with right-, left-, and interval-censored data; and PROC LIFETEST for data that are right-censored. LIFETEST computes nonparametric estimates of the survival distribution and computes rank test for association of the response variable with other variables. The survival estimates are computed within defined strata levels, and the rank tests are pooled over the strata and are therefore adjusted for strata differences. The Weibull distribution is one of several distributions that can be allowed in the LIFEREG procedure. Other distributions include exponential, gamma, and lognormal. (Reference, SAS manual chapters 15, 25, 26 - LIFEREG, LIFETEST)

5.3.2 Weibull Analysis. A Weibull Analysis is a statistical technique useful for various aspects of failure analysis which provides accurate failure predictions for an entire population based on limited failure data. The <u>Weibull Analysis Handbook</u> (AFWAL-TR-83-2079) provides instructions in the use of Weibull Analysis. The <u>Weibull-Based Parts Failure Analysis Computer Program User's Manual</u> (NADC-89089-60), provides the background and describes the usage of computer codes used to analyze failure characteristics using the Weibull distribution. Weibullsmith™ software is a useful tool for performing Weibull analysis. Weibull Analysis can provide information such as the following:

a. The conditional probability of failure of a part at a given age

b. The expected number of failures over any future time period (Values of the Weibull slope can be compared with historical trends of other equipment in order to fit the type of failure characteristics)

c. The type of failure mode, i.e. infant mortality, wear-out, batch problems, combinations of failure modes, etc.

d. The percentage of items expected to fail by a given age

e. The impact of design changes on failure risk

f. The number of samples required for specific AE inspections

The advantages of the Weibull analysis methodology are that it provides the following:

a. A graphical solution by analysis of plotted curves

b. The type of analysis relating to slope of possible failure modes can be expanded by inspecting libraries of past Weibull curves

c. It is useful even with inadequate data such as small samples, mixtures of failure modes, chart origin being other than zero, use of alternate scales other than time; nonserialized parts or components where the time accumulated on the part cannot be clearly identified, and the construction of a Weibull curve when there is not failures at all, only success data

d. Little difficulty making graphic comparisons to determine best distributions fit to the data because there are only a few alternatives in the Weibull distribution

e. Weibull analysis can be performed by new engineers after training provided by the manual

f. The manual contains all of the above curves and background for operating the methodology, including two computer programs for estimating Weibull distribution for both complete and censored samples

5.3.3 Monte Carlo Analysis. Monte Carlo techniques give you a way of simulating variations in complex non-linear models without running every possible condition. The entire system (weapon system) having various failure modes can be analyzed using this technique. A Monte Carlo simulation can forecast future risk and is necessary when validating a risk analysis. You must know what the underlying equations are before applying some type of random distribution of variables in your equation.

5.3.4 Actuarial Analysis. Actuarial analysis is the process of using life data from an appropriate sample to determine the effect of aging on the conditional probability of failure. The primary use of actuarial analyses is to determine wear-out times for either a rework tasks or life-limits. EHR cards are an excellent method for acquiring the life data required for performing an actuarial analysis. Note that actuarial analysis requires life data, meaning the ages at which all failures occur, not simply a count of failures during some particular time period. The usual objective of an actuarial analysis is to determine the applicability and effectiveness of a scheduled rework or discard task. These analyses can also be used to establish effective intervals for such tasks, or to identify, by separate examination, the impact of the dominant EFMs on the overall age reliability relationship. For application of actuarial analysis to hardware, there are two products of interest; the conditional probability of failure curve and the survival curve.

The conditional probability curve (examples in FIGURE 5-1), sometimes called the hazard curve, shows the influence of age on the probability of failure in a continuous series of time intervals. This probability is called a conditional probability, because it presumes that the item survives to enter each successive interval. The shape of the conditional probability curve determines whether a HT task can be applicable. A scheduled rework task is applicable only if there is some age at which an item shows a rapid increase in the conditional probability of failure. This age is not related to the MTBF.

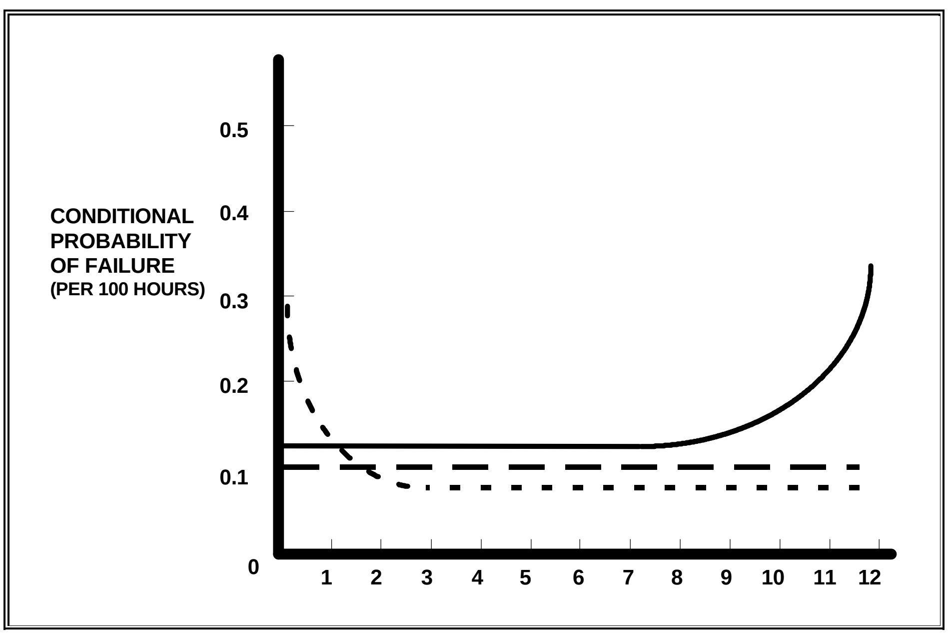

FIGURE 5-1. Conditional Probability of Failure Curves

The survival curve shows the probability of an item surviving to a particular age (examples in FIGURE 5-2). The Survival Curve is used to determine the percentage of items that will survive to the wearout age. The percentage of units that survive determine, in part, the applicability of the HT task. See Appendix E for an example of an actuarial analysis.

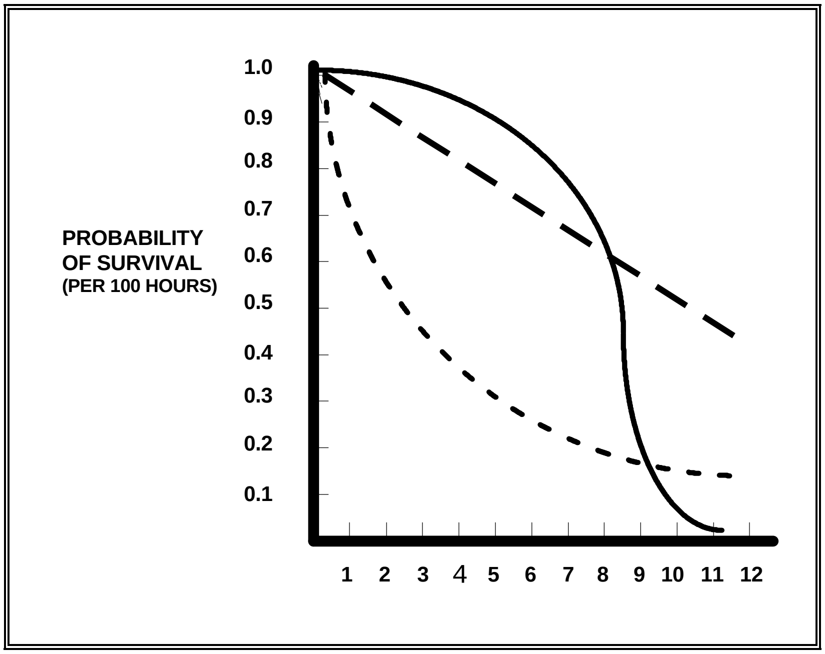

FIGURE 5-2. Survival Curves

5.4 Fracture Mechanics. Fracture mechanics is an analytical method for determining crack growth rates. Fracture mechanics analysis predicts the number of cycles of some applied load required to "grow" a crack from detectable size to critical size at which complete fracture of the part occurs. Its primary input into the RCM analysis is the detectable and critical crack life (interval from potential to functional failure) for SSI items subject to cracks.